CSCanada
Advances in Petroleum Exploration and Development
Vol. 11, No. 1, 2016, pp. 35-41
DOI:10.3968/8163

ISSN 1925-542X [Print]
ISSN 1925-5438 [Online]
www.cscanada.net
www.cscanada.org

Research on Reservoir Prediction With High Precision Based on the Control of Logging and Seism

LIU Yikun[a]; CAO Yu[a]; LIANG Shuang[a],*; LIU Xue[a]; ZHANG Miao[a]

[a] Key Laboratory of Enhanced Oil and Gas Recovery of the Ministry of Education, Northeast Petroleum University, Daqing, China.
*Corresponding author.

Received 30 January 2016; accepted 3 March 2016
Published online 31 March 2016

Abstract

With the continuous development of detailed reservoir description technology, the research of multiple disciplines reservoir based on the geological cognition has gradually carried out in Daqing oilfields. In this paper, the research mainly studied Putaohua oil layer of Xingshi district, and the study about the method of improving the reservoir prediction accuracy was carried out after finishing the basic data, geological statistics formation, fine seismic horizon interpretation and fault interpretation which based on the combination of logging and seism. Optimize the properties for predicting the structure through seismic attribute and post-stack density pseudo wave impedance inversion to realize quantitative characterization of sandstone and mudstone threshold value by seismic attributes, and coincidence rate showed that, the prediction accuracy of interwell channel sand body reached 85%, and results of block application showed that narrow channel sand had better continuity after the combination of logging and seism, boundary and swing position of river changed large, and interwell connectivity is more accurate, which provides a more reliable basis for the further development of the residual oil in channel sand bodies.

Key words: Combine logging and seism; Attribute optimization; Inversion; Threshold value; Forecasting

Liu, Y. K., Cao, Y., Liang, S., Liu, X., & Zhang, M. (2016). Research on reservoir prediction with high precision based on the control of logging and seism. *Advances in Petroleum Exploration and Development*, *11*(1), 35-41. Available from: URL: http://www.cscanada.net/index.php/aped/article/view/8163
DOI: http://dx.doi.org/10.3968/8163

INTRODUCTION

The research area is the middle of the Xingnan development area, where the structure is relatively gentle, and the northern region is slightly higher, the structure change trend, in a word, is slightly different from each side. The three sets of formation are SII, SIII, and the PI oil layers belonging to the large fluvial-delta deposition in the northern Songliao basin[1]. Sheet sand of outside delta-front fancies mainly distributed in Sa'ertu reservoirs with fine sandstone grain and siltstone is primary lithology; while channel sand of delta distributary plain and inside delta-front facie mainly distributed in PI oil layers and fine siltstone is the primary sand. When it comes to fine interpretation of the area, seismic data in 2009 was used, that the surface element: 10 m × 10 m, the sampling rate: 1 ms, range of line: Inline: 70~343, trace: 932~1,982. By the end of 2011, the multi discipline research work of reservoir has completed in most of the Daqing placanticline which is mainly based on data of wells[2-4]. In 2010, full coverage of multidisciplinary reservoir research results has achieved in Xingnan development area, so that history matching precision of geological model established by using geological understanding of well data can get more than 80%, but history matching precision of some individual wells and layers are still low, which is not conducive to the fine adjustment and potential tapping, and the main factors affecting history matching precision is geological understanding accuracy[5].

At present, the reservoir prediction can only be qualitative or semi quantitative, and the error of quantitative prediction is larger, which reflects the difficulty of reservoir prediction with seismic data[6]. Seismic prediction work of reservoir is mainly divided into four aspects: Reservoir lithology prediction, reservoir shape prediction, reservoir physical properties prediction and reservoir oil and gas comprehensive analysis[7]. In recent years, the stochastic simulation seismic inversion technology is developing, which can realize the combination of seismic inversion and geostatistical simulation technology to maximize the use of seismic, geological and logging data, so that the inversion results can fully conform to the known conditions[8-9]. Foreign combination of well and seismic technology development is mainly manifested in the following aspects: In 1971, gal'perin academician from Academy of Sciences of the USSR published monograph "vertical seismic profiling", laying a foundation for the application and development of vertical seismic profile method[10]. Abroad multiwave and multicomponent seismology develop faster than China, which has good application in rock physics research, conversion wave prestack migration, and conversion wave interpretation[11-12]. In order to further improve the precision of reservoir prediction, this study is located in Xingshi oil field of Xingnan development area where has water flooding fine potential tapping demonstration block, through optimization of seismic attributes and quantitative characterization of sandstone and mudstone threshold value by seismic attributes, so as to describe the boundary and direction of the river channel sand body, and improve the prediction accuracy of the river sand.

1. STUDY ON THE METHOD OF COMBINATION OF WELL AND SEISMIC TECHNOLOGY TO IMPROVE THE ACCURACY OF RESERVOIR PREDICTION

1.1 Optimization of Seismic Attributes

Seismic attribute optimization is the key of seismic attribute analysis[13]. Seismic attribute optimization method in this paper based on the mathematical theory, and more than 1,000 oil or water wells in the study area with the minimum well spacing up to 100 m, so that statistical effect are clear enough to express prediction effect. The attribute optimization steps are as follows:

(a) Preliminary select seismic attributes: Get rid of the seismic attributes used for the prediction of structures to identify the channel sand bodies, and determine the channel sand body boundary and direction.

(b) Attribute dimension reduction: Keep a property through artificial screening among those picked up using different calculation methods, but connection between them is consistent under certain conditions, such as total energy and average energy, the difference is a coefficient under the condition of the same time window.

(c) Select the seismic attributes with high coincidence rate: The coincidence rate is used to describe the separation degree between the well logging and seismic attributes.

Take a correlation analysis on total thickness of class I sandstone, maximum thickness of class Ⅰ sandstone, total thickness of class Ⅱ sandstone, maximum thickness of class Ⅱ sandstone, total thickness of effective sandstone, maximum thickness of effective sandstone respectively with along layer amplitude, maximum peak amplitude, reflection intensity, root mean square amplitude, top and bottom amplitude difference, the ratio of longitudinal and transverse wave velocity and the density pseudo wave impedance. The results show that the ratio of longitudinal and transverse wave velocity, density pseudo wave impedance and the thickness of sandstone have relatively high correlation, so select the ratio of longitudinal and transverse wave velocity and density pseudo wave impedance to count the coincidence rate, as shown in Table 1.

Correlation analysis of 11 sedimentary units of $PI1_{1a}$-$PI3_{3b}$ oil layers were carried out using this method, the value of the ratio of longitudinal and transverse wave velocity and density pseudo wave impedance of each sedimentary unit were higher than other seismic attributes when correlate with well logging parameters, so the ratio of longitudinal and transverse wave velocity and density pseudo wave impedance of each sedimentary units were ultimately selected to predict the reservoir.

Table 1
Analysis of the Sandstone Thickness and Seismic Attributes of $PI2_{1b}$ Sedimentary Unit

Sandstone thickness	Density pseudo wave impedance	Along layer amplitude	Amplitude difference	Maximum peak amplitude	Reflection intensity	Root mean square amplitude	The ratio of longitudinal and transverse wave velocity
Total thickness of class I sandstone	-0.341	0.172	0.187	-0.015	0.135	0.157	0.367
Maximum thickness of class Ⅰ sandstone	-0.335	0.171	0.180	-0.015	0.134	0.155	0.357
Total thickness of class II sandstone	-0.323	0.170	0.187	-0.008	0.134	0.162	0.350

To be continued

Continued

Sandstone thickness	Density pseudo wave impedance	Along layer amplitude	Amplitude difference	Maximum peak amplitude	Reflection intensity	Root mean square amplitude	The ratio of longitudinal and transverse wave velocity
Maximum thickness of class II sandstone	-0.318	0.167	0.174	-0.009	0.133	0.160	0.338
Total thickness of effective sandstone	-0.342	0.182	0.193	-0.008	0.141	0.159	0.377
Maximum thickness of effective sandstone	-0.325	0.176	0.173	-0.012	0.132	0.145	0.354

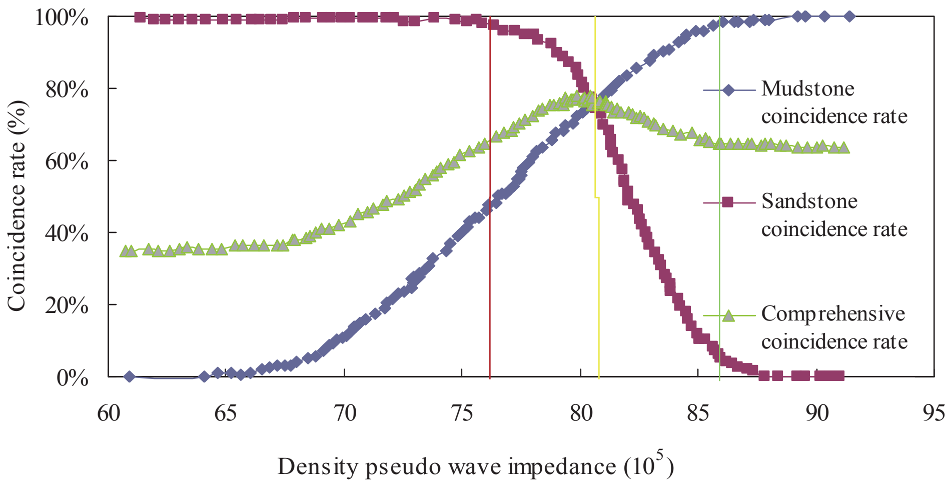
1.2 Quantitative Characterization of Threshold Value of Sandstone and Mudstone by Seismic Attributes

There is no quantitative characterization method of the threshold value of sandstone and mudstone by seismic attributes and seismic inversion for a long time[14]. The same attribute with different threshold values has a great influence on the effect of planar graphs palette into graph, and difference of sandstone and mudstone coincidence rate are also great, before the threshold value only determined by the qualitative judgment, it is difficult to identify the optimal threshold value. In this paper, establish programs to statistically analysis the coincidence rate of sandstone, mudstone and channel sand body with thickness greater than 1m to wells automatically, when setting the threshold value of different attribute values. Specific steps are as follows:

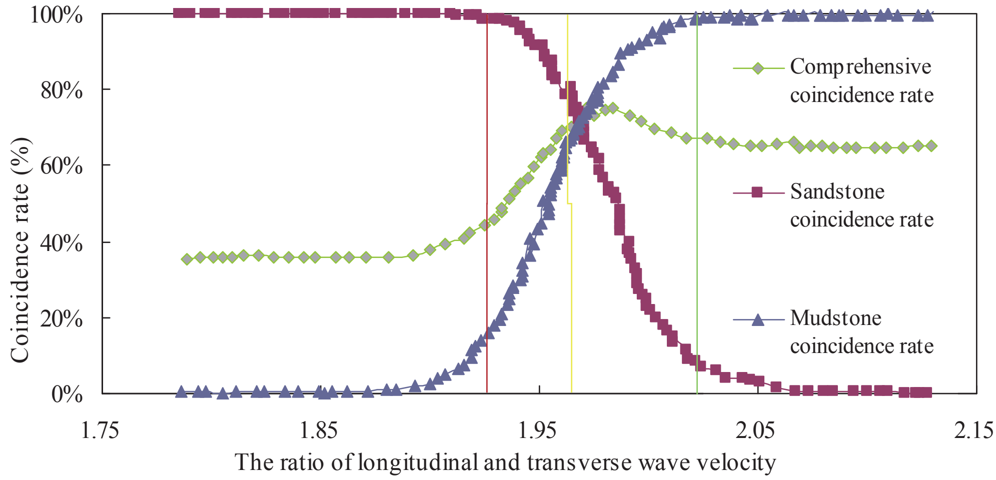
(a) Make scatter diagram of the seismic attribute value and the sand thickness, determine the correlation between the value of the attribute and the thickness of the sandstone, and apply programs to statistically analysis the coincidence rate of predicted lithology and actual wells data under different threshold values.

(b) Draw curve of the sandstone, mudstone and comprehensive coincidence rate at different threshold value, determine the optimal threshold value and the dominant area of sandstone and mudstone. Select corresponding point with the highest comprehensive coincidence rate as the optimal threshold value, and select the corresponding point with the highest sandstone and mudstone coincidence rate as dividing point to determine the dominant region of sandstone and mudstone.

(c) According to these 3 marks, the seismic attribute slices are divided into 4 sections (Figure 1), which can reflect the distribution of the sand body better, and improve the accuracy of the work (Figure 2).



(a) Curve of Density Inversion Coincidence Rate of PI2



(b) Rate Curve of Longitudinal and Transverse Wave Velocity of PI2

Figure 1
Coincidence Rate Curve When Attribute Value of Each Well Is Seen as the Threshold Value of $PI2_{1b}$

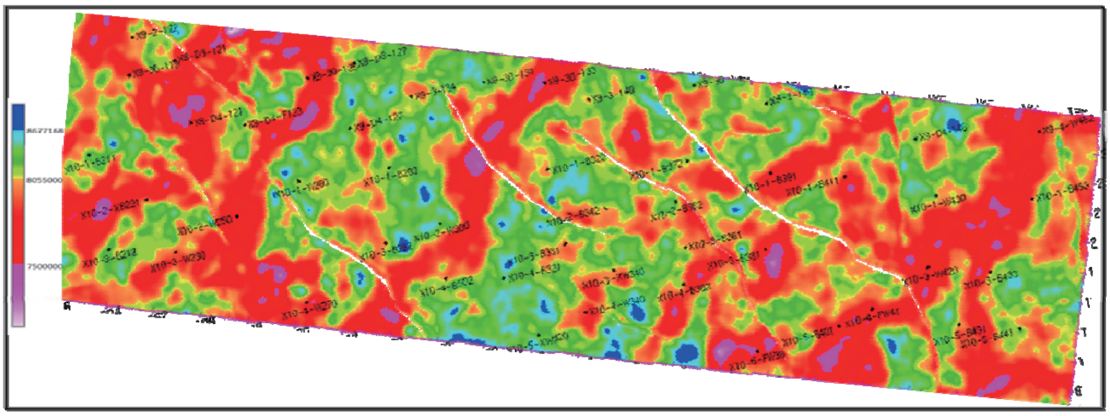


Figure 2
Toning Results of Four Interval With Density Inversion of $PI2_{1b}$

1.3 Coincidence Rate Analysis

The 50 wells which have acoustic time difference curve with no high resolution, far from fault and uniform distribution are selected as checkout well. The maximum sandstone thickness of the sedimentary units with reservoir prediction results are compared to count coincidence rate. There are 50 wells in PI3 unit, and 24 wells are developed micro phase of channel accounting for 48% of the total number of wells among them, of which 21 wells are in line with the prediction result, the coincidence rate is 87.5%, as Table 2. According to the rate statistics method, the seismic attributes and the inversion results of other sedimentary units are verified and analyzed as this, and the prediction accuracy of channel sand bodies among wells is 85%.

Table 2
Statistics on the Coincidence Rate of Along Layer Amplitude Attribute With the Corresponds Wells of Channel Phase in PI31 Sedimentary Unit

Well number	Microfacies type	Amplitude attribute value	Coincidence situation	Well number	Microfacies type	Amplitude attribute value	Coincidence situation
X10-1-B211	Channel	-1,386.88	Matched	X10-4-B362	Channel	375.85	Matched
X10-1-B391	Channel	672.24	Unmatched	X10-4-FW41	Channel	-1,015.52	Matched
X10-1-W260	Channel	-6,159.95	Matched	X10-4-W340	Channel	-853.59	Matched

To be continued

Continued

Well number	Microfacies type	Amplitude attribute value	Coincidence situation	Well number	Microfacies type	Amplitude attribute value	Coincidence situation
X10-1-W430	Channel	771.12	Unmatched	X10-5-FW38	Channel	289.37	Matched
X10-2-W250	Channel	-1,015.41	Matched	X9-3-146	Channel	-2,652.29	Matched
X10-2-XB221	Channel	-2,669.41	Matched	X9-30-119	Channel	-6,484.56	Matched
X10-3-B212	Channel	-5,093.75	Matched	X9-30-125	Channel	369.41	Matched
X10-3-B282	Channel	309.86	Matched	X9-2-122	Channel	-6,332.96	Matched
X10-3-B331	Channel	-1,650.46	Matched	X9-3-134	Channel	-2,003.42	Matched
X10-3-B381	Channel	412.14	Unmatched	X10-4-B302	Channel	-1,485.34	Matched
X10-3-W230	Channel	-1,175.33	Matched	X9-D3-127	Channel	-1,574.61	Matched
X10-4-B321	Channel	-114.73	Matched	X9-D4-F123	Channel	-4,494.39	Matched

2. CASE ANALYSIS

Aim at four kinds of attribute slices of eleven sedimentary units, according to three threshold values, count the proportion and coincidence rate of channel and thin-out area in the four attribute range. The effect of each seismic attribute in PI group is in Table 3.

Table 3
Application of Seismic Attributes in Different Sand Bodies

Sandbody	Attributes	Application
Distributary plain phase and recession inner front sand body	Density pseudo wave impedance inversion and amplitude properties	Determination of the main channel area and the continuity
	Velocity ratio of longitudinal and transverse waves and density pseudo wave impedance inversion	Determine variation zone
Progressive flooding inner front sand body	Density pseudo wave impedance inversion and amplitude difference attribute	Determine variation zone
Outer front sand body	No effect attribute	Reflect the local scale of the residual underwater diversion channel sand

At the same time, pattern drawing method was used in the position of the near fault, the boundary of the area, and the plane interference to express the real well-point data.

2.1 The Characteristics of Sand Body After the Combination of Well and Seismic

At present, phase belt graphs of eleven sedimentary units of PI 1-3 oil layers are drawn using pattern drawing method. By comparing new and old sedimentary phase belt graph, sand body distribution on the unit layer have a little change, and specific changes mainly reflected on the following aspects:

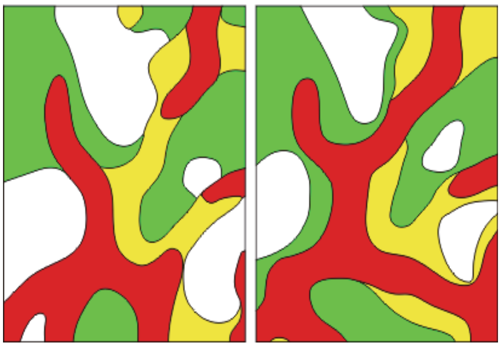
(a) Narrow channel sand is more continuous, as shown in Figure 3.

(b) The change of the channel width is almost small, but there is a slight deviation of the swing position, as shown in Figure 4.

(c) Due to the channel sand, interchannel sand, and narrow channels change greatly, the wells connectivity is more accurate, as shown in Figure 5.

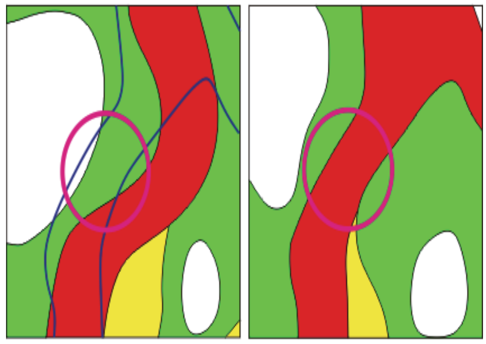
2.2 The Results Verification

Well X10-2-B2222 of $PI2_2$ oil layer showed no inflow direction in the original facies map, but in the new facies map, the layer has good communicate with injection wells X10-1-W 230, which reflects the superiority of new facies belt graph (Figure 6).



(a) (b)

Figure 3
Facies Map Before (a) and After (b) the Combination of Well Logging and Seismic of PI2$_{1b}$



(a) (b)

Figure 4
Facies Map Before (a) and After (B) the Combination of Well Logging and Seismic of PI2$_{1b}$

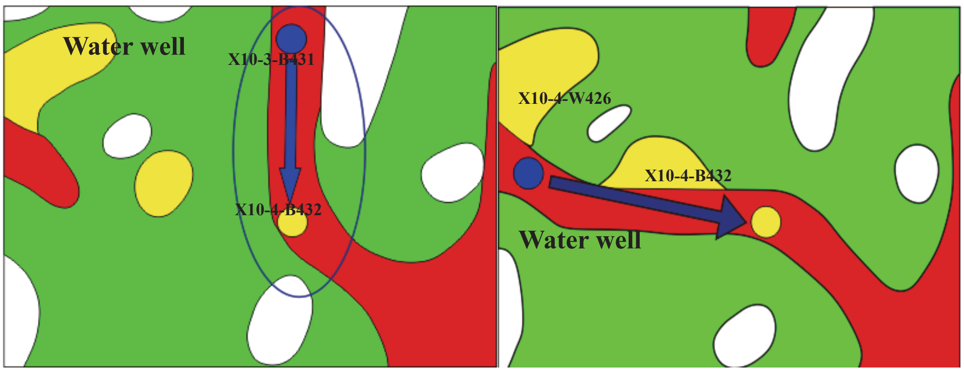


Figure 5
Facies Map Before (a) and After (b) the Combination of Well Logging and Seismic of PI2$_{1b}$

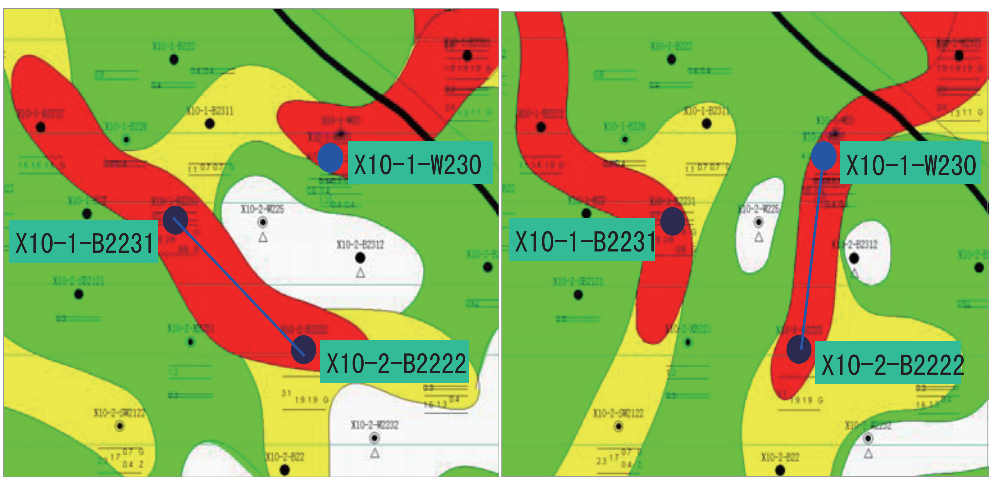


Figure 6
Facies Map Before (a) and After (b) the Combination of Well Logging and Seismic of PI2$_{1b}$

CONCLUSION

(a) Based the mathematical theory, the seismic attributes optimization method are established, density pseudo wave impedance and longitudinal and transverse wave velocity ratio are ultimately selected for reservoir prediction.

(b) Form the sandstone and mudstone quantitative characterization method of the threshold value based on seismic attribute, which makes the attribute slices can reflect the distribution of sand body better, and improve the efficiency and accuracy of the work.

(c) The well and seismic combination mapping methods has formed, mainly narrow channel continuous is better, channel boundary and channel swing position are larger, and interwell connectivity is more accurate.

REFERENCES

[1] He, L. (2012). *Injection method research of polymer flooding pilot area in PI3 layer* (Doctoral dissertation). Xing Nan Development Zone, Zhejiang University, Hangzhou, China.

[2] Chen, K. Y., Yang, W., & Wu, Q. L. (2013). Preliminary study on the wave field separation of seismic reflection wave and scattered wave. *Lithologic Reservoirs*, *2*, 76-81.

[3] Chen, K. Y., Wu, Q. L., & Li, L. L. (2012). Reservoir heterogeneity and its relation with remaining oil distribution in the Matouzhuang oilfield. *Lithologic Reservoirs*, *2*, 87-91+116.

[4] Hang, L. Q. (2007). Optimization of upward strata combination of second class oil layer in eastern south Ⅱ area of Daqing oilfield. *Lithologic Reservoirs*, *4*, 116-120.

[5] Yu, K. C., Zhu, Y., & Meng, Y. (2012). Description and application of well seism combined with fine structure in Taibei development zone. *Journal of Northeast Petroleum University*, *4*, 49-53+7.

[6] Tao, Y. G., Yuan, G., Chen, X. A., Niu, H. Y., Kong, X., & Zhao, W. D. (2007). Application of relative amlitude method to merging processing of 2-D seismic data and reservoir prediction technique in the southwestern Tarim. *Lithologic Reservoirs*, *1*, 21-25.

[7] Ni, F. T. (2008). *Reservoir parameter predicted method research based on seismic attribute analysis* (Doctoral dissertation). China University of Petroleum, Beijing, China.

[8] Liu, W. F., Duan, Y. H., & Gao, J. H. (2007). A method study of carbonate reservoir identification by using post-stack seismic data. *Lithologic Reservoirs*, *1*, 101-104.

[9] Zhao, W. J., Zhang, Q. F., & Su, Q. (2010). Seismic reservoir characteristics and predicting techniques for Moliqing rift. *Lithologic Reservoirs*, *4*, 100-103.

[10] Guo, J. (2004). Application status and development trend of VSP technology. *Process in Geophysics*, *27*(1), 3-8.

[11] Caldwell, J. (1999). Marine multi-component seismology. *The Leading Edge*, *18*(1), 1274-1276.

[12] Zhang, X. B., Li, Y. L., & Tang, J. H. (2003). Using multi-wave data to detect fractures. *Oil Geophysical Prospecting*, *38*(4), 431-438.

[13] Bao, X. S., Yin, C., & Zhao, W. (2006). Optimizing selection of seismic attributes in reservoir prediction. *Geophysical Prospecting for Petroleum*, *1*, 28-33.

[14] Zhang, Y. M., Zhang, S. F., & Qian, L. (2008). Sandstone porosity inversion based on seismic data. *Geophysical Prospecting for Petroleum*, *2*, 136-140.

